Biosignals and Systems

Lecture 6

Electromyography

Objectives

At the end of the session, you should be able to:

- Discuss the principles of EMG
- Describe the characteristics of normal EMG
- Describe the characteristics of abnormal EMG

Definition

- Study of muscle function through the examination of electrical signals
  - 'Electro' – electric
  - 'Myo' – muscle
  - 'Graphy' – to graph / to measure
- Why use EMG?
  - *In vivo* examination of muscle activity
  - Quantifies muscle activities
  - Clinical vs. Kinesiological

History

- 1791
  - Luiggi Galvani, depolarized frog legs with metal rods
- 1838
  - Carlo Matteucci, proved electrical currents originated in mm
- 1849
  - Du Bois-Reymond, designed a galvanometer, reduced impedance by popping blisters

History

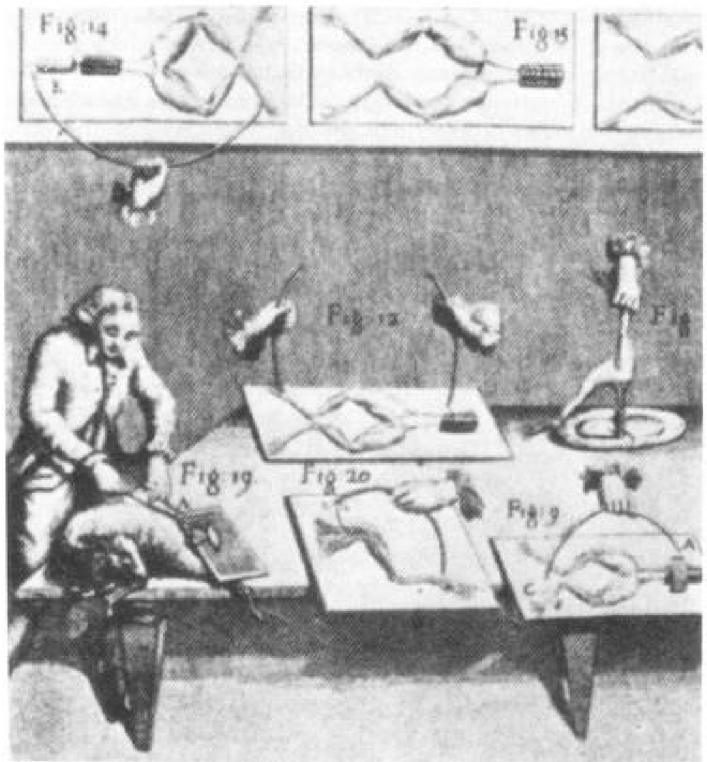


Figure 1.2. Galvani's demonstrations of the effects of electricity on muscles of frogs and sheep. (From Fulton's reproduction of a plate in Galvani's *De Viribus Electricitatis in Motu Musculari Commentarius*, 1792.)

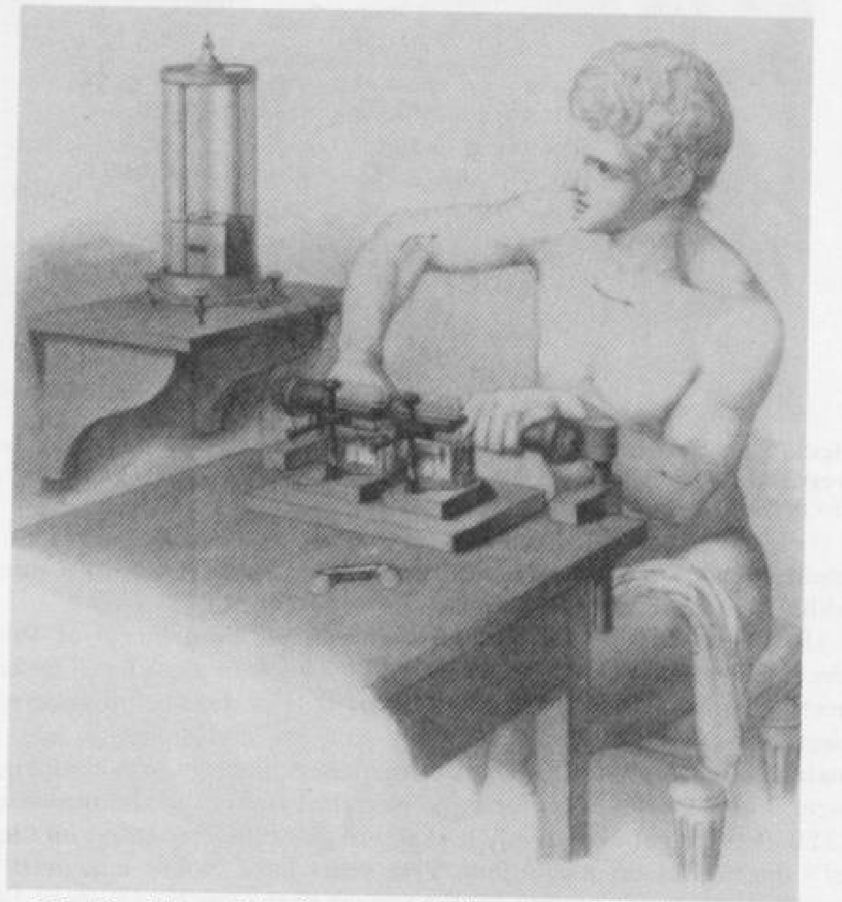
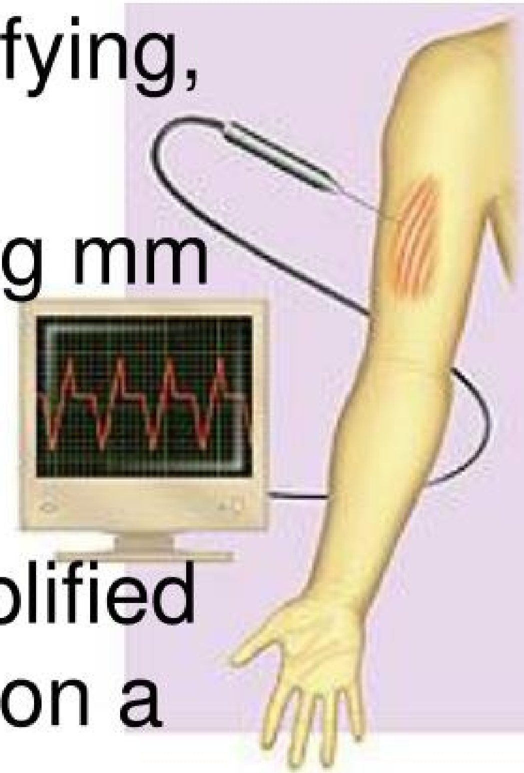


Figure 1.3. Depiction of the first recorded detection of the EMG signal from human muscles during voluntary contraction. (From Figure 147 of the book *"Uber Thierische Elektricitat"* by Du Bois-Reymond published in 1849.)

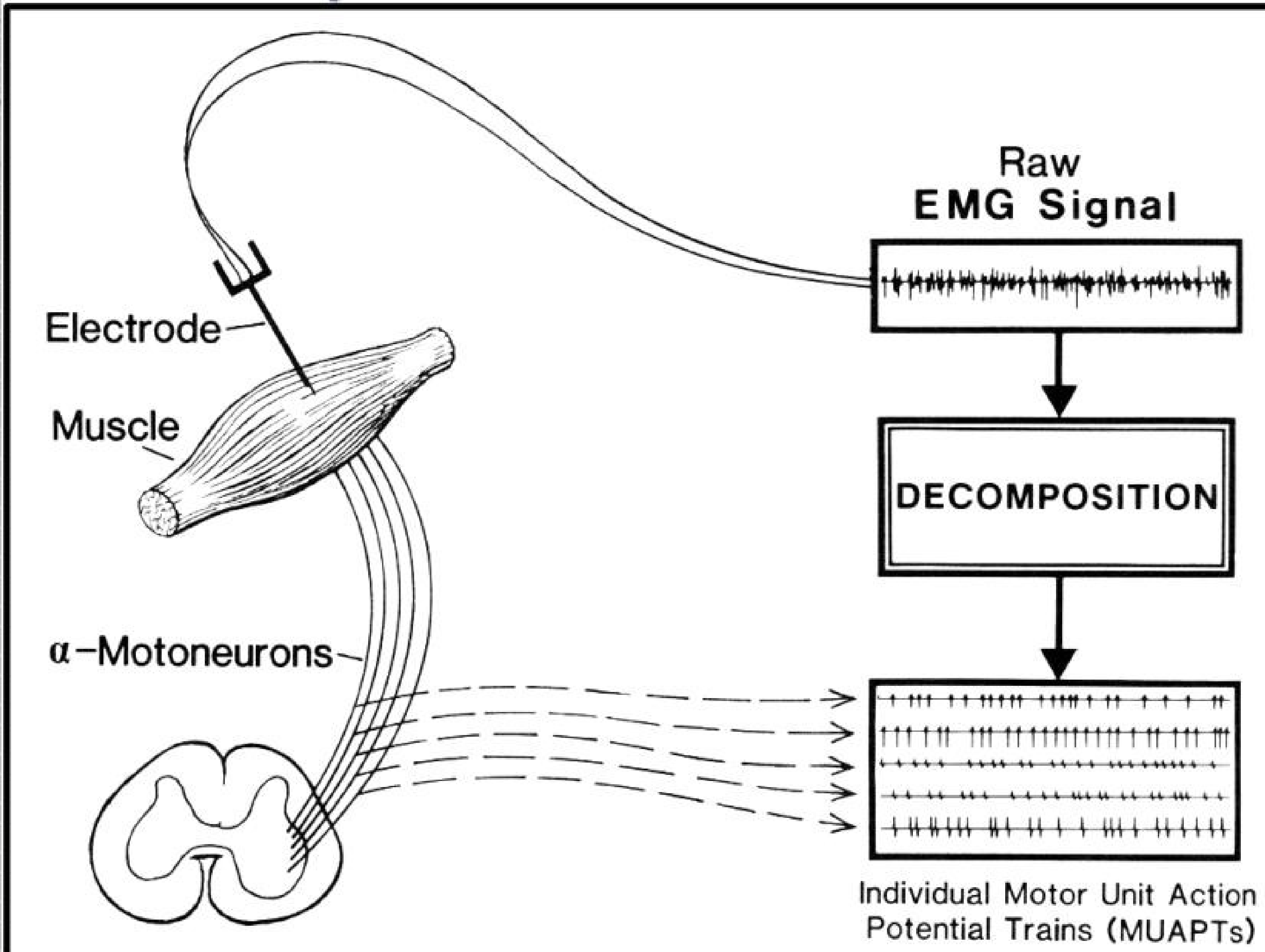
Principles

- Involves detecting, amplifying, and displaying electrical changes that occur during mm contraction



- Electrical events are amplified electronically, visualized on a tv-like monitor or even transformed into sound

Principles



Raw
EMG Signal
Electrode
Muscle
DECOMPOSITION
α−Motoneurons
Individual Motor Unit Action Potential Trains (MUAPTs)

HOW CAN WE DETECT ELECTRICAL SIGNALS?

Electrodes

- Transducer; device converting one form of energy to another
- Different types
  - Surface electrodes
  - Fine – wire indwelling electrodes
  - Needle electrodes

Electrodes

Surface Electrodes

- Applied on the surface of the skin
- Measures signals from large muscles that lie close to the skin
- Often silver/silver chloride, coated with a suitable conducting gel, and can be taped on the skin

Electrodes

Fine-wire Indwelling Electrodes

- Two strands of 100micro-meter wires inserted into the muscle belly
- Used for monitoring activity from deep mm, small mm, or narrow mm
- May not be useful for large mm

Electrodes

Needle Electrodes

- Used to record motor unit potentials from different parts of the muscle
- Fine needles with electrodes inserted into the muscle
- The bare tip of the needle serves as the recording electrode

Electrodes

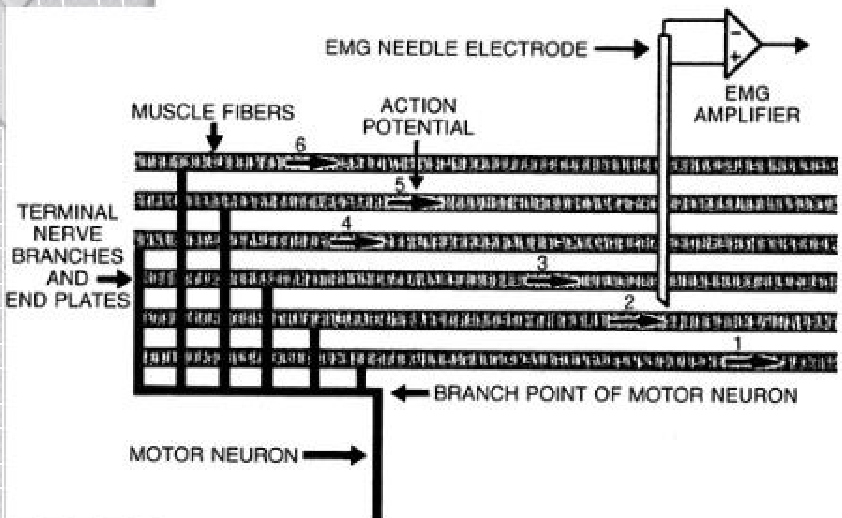
Recording / Detection Electrode

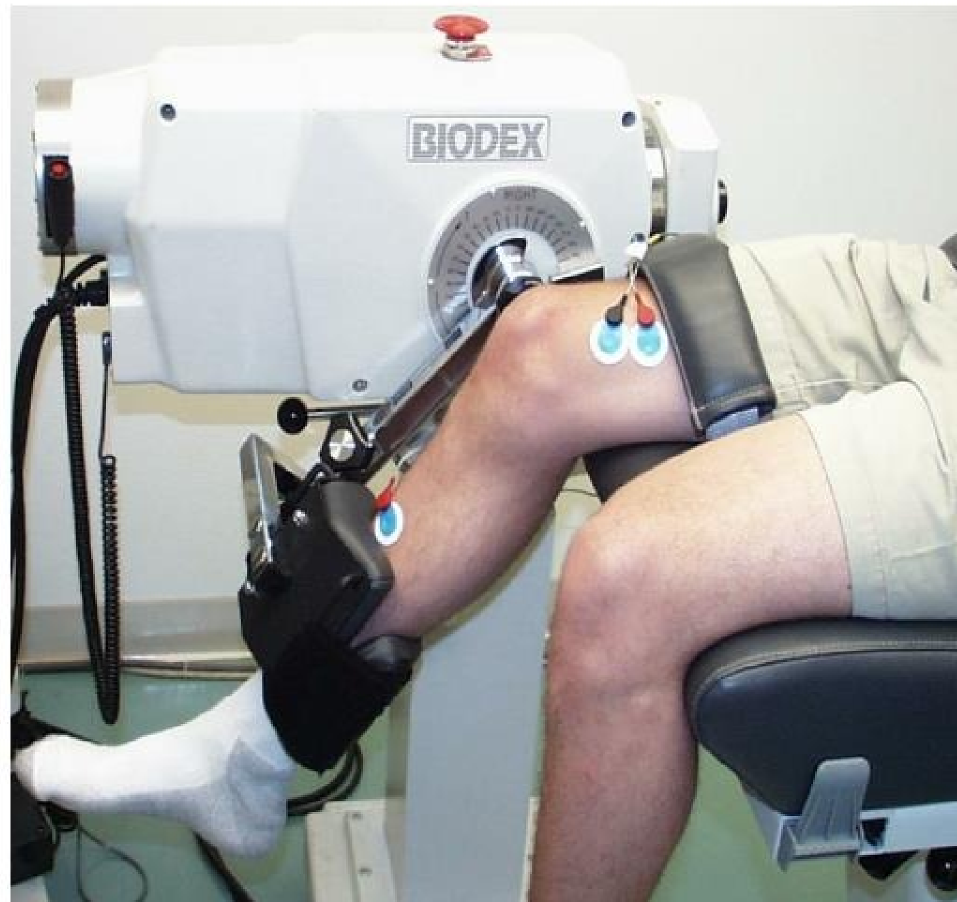
- Either surface, needle, or fine-wire

Ground Electrode

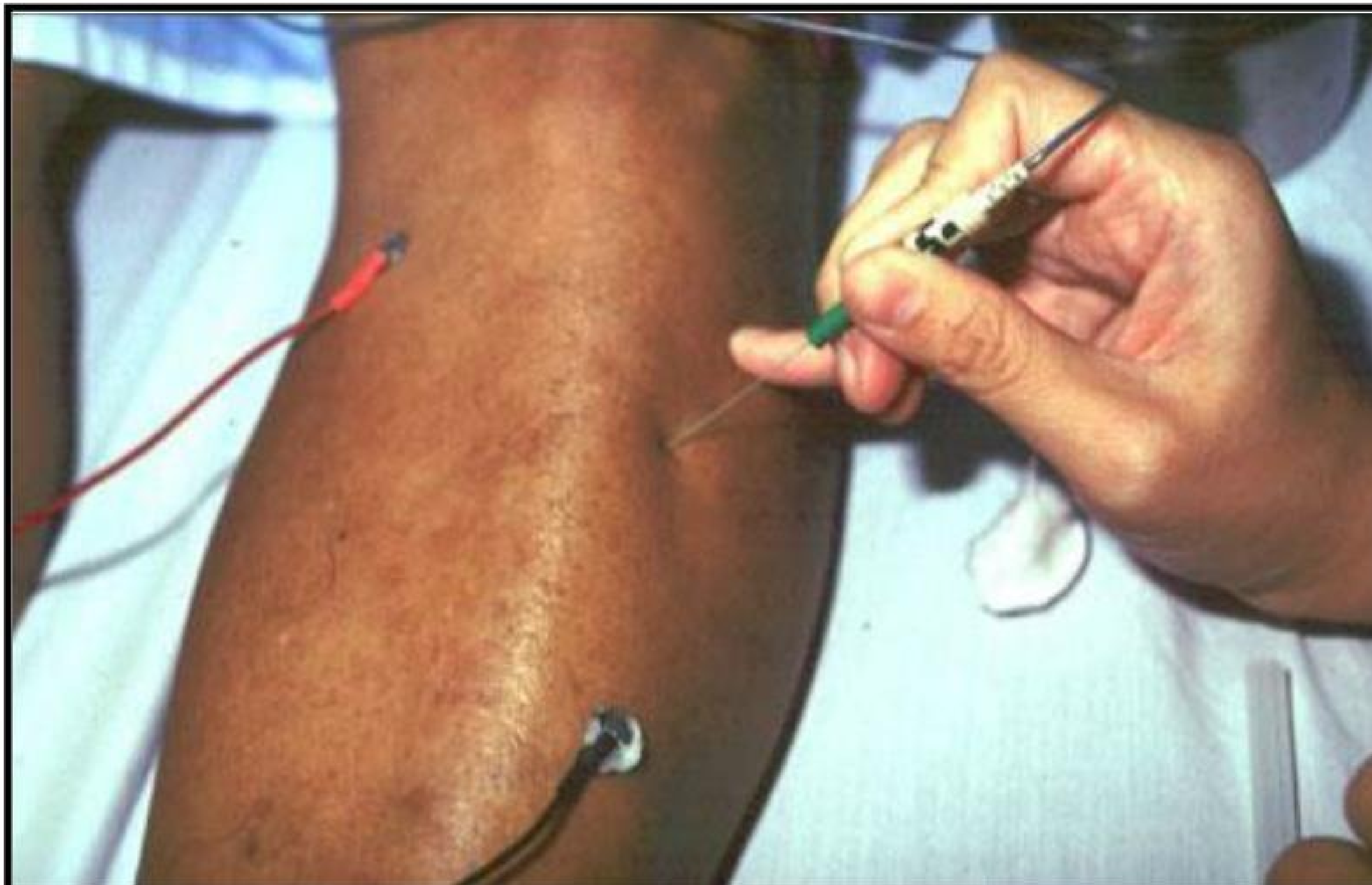
- Provides a mechanism for cancelling out the interference effect from external noise
- Surface electrode
- Attached near the recording electrode

Electrodes

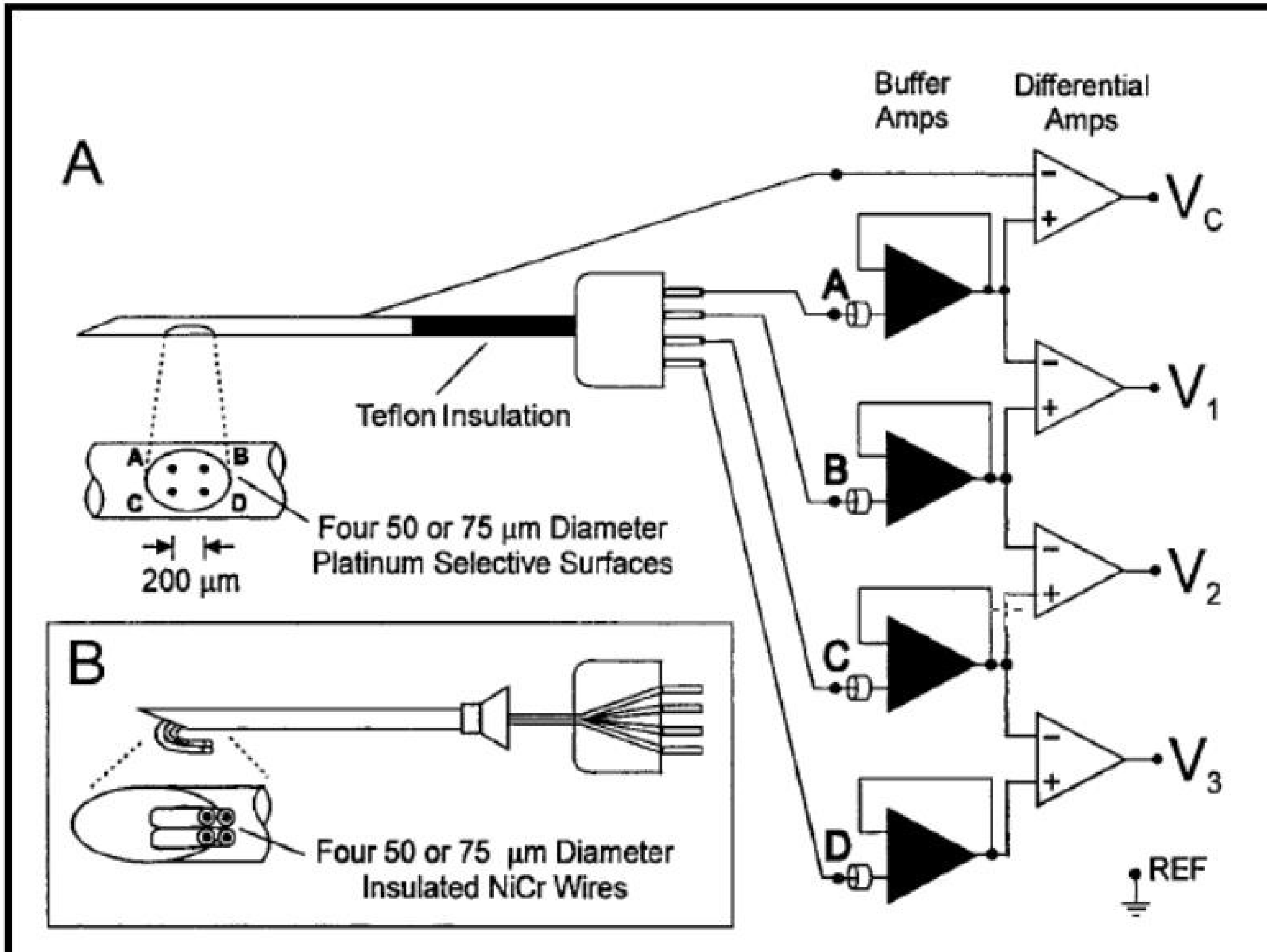

EMG NEEDLE ELECTRODE
EMG AMPLIFIER
MUSCLE FIBERS
ACTION POTENTIAL
6
5
4
3
2
1
TERMINAL NERVE BRANCHES AND END PLATES
BRANCH POINT OF MOTOR NEURON
MOTOR NEURON


BIODEX

Electrodes



Electrodes



A
Buffer Amps
Differential Amps
Teflon Insulation
A
B
C
D
Four 50 or 75 µm Diameter Platinum Selective Surfaces
200 µm
V_C
V_1
V_2
V_3
REF
B
Four 50 or 75 µm Diameter Insulated NiCr Wires

Myoelectric Signal

Variables that may affect MUAP

- Proximity of electrodes to the fibers that are firing
- Number and size of fibers in the motor unit
- Distance between the fibers
- Size of the electrodes
- Distance between the electrodes

Myoelectric Signal

Cross – talk

- Electrical overflow
- Electrical activity from nearby contracting muscles reaches the electrodes
- Controlled by:
  - Careful electrode placement, spacing, choice of size and type of electrode

Myoelectric Signal

Artifacts

- Unwanted electrical activity
- Arises outside of the tissues beinng examined
- May distort output signals markedly
- Sources
  - Movement
  - Power line
  - ECG

Myoelectric Signal

Movement Artifact

- Skin
- Electrode
- Contracting muscle
- *Electrode cables*
  - Produces high voltage, high frequency artifacts
- Controlled by:
  - Firm fixation of electrodes, firmly taping cables, skin preparation

Myoelectric Signal

Power line Interference

- Human body attracts electromagnetic energy from power lines
- Loose electrode attachments, broken or frayed electrodes, broken electrode wires
- Diathermy, ES, cellphones, radios, vibrators

Myoelectric Signal

ECG

- can occur if electrodes are placed on the trunk, upper arm, or upper thigh
- How to reduce this artifact?
  - Correct application of ground electrode
  - Use of amplifier with appropriate characteristics

Amplifier

Signals (microvolts) recorded have to be amplified about a thousand times for them to be displayed on an oscilloscope and be heard through speakers or be recorded on a chart

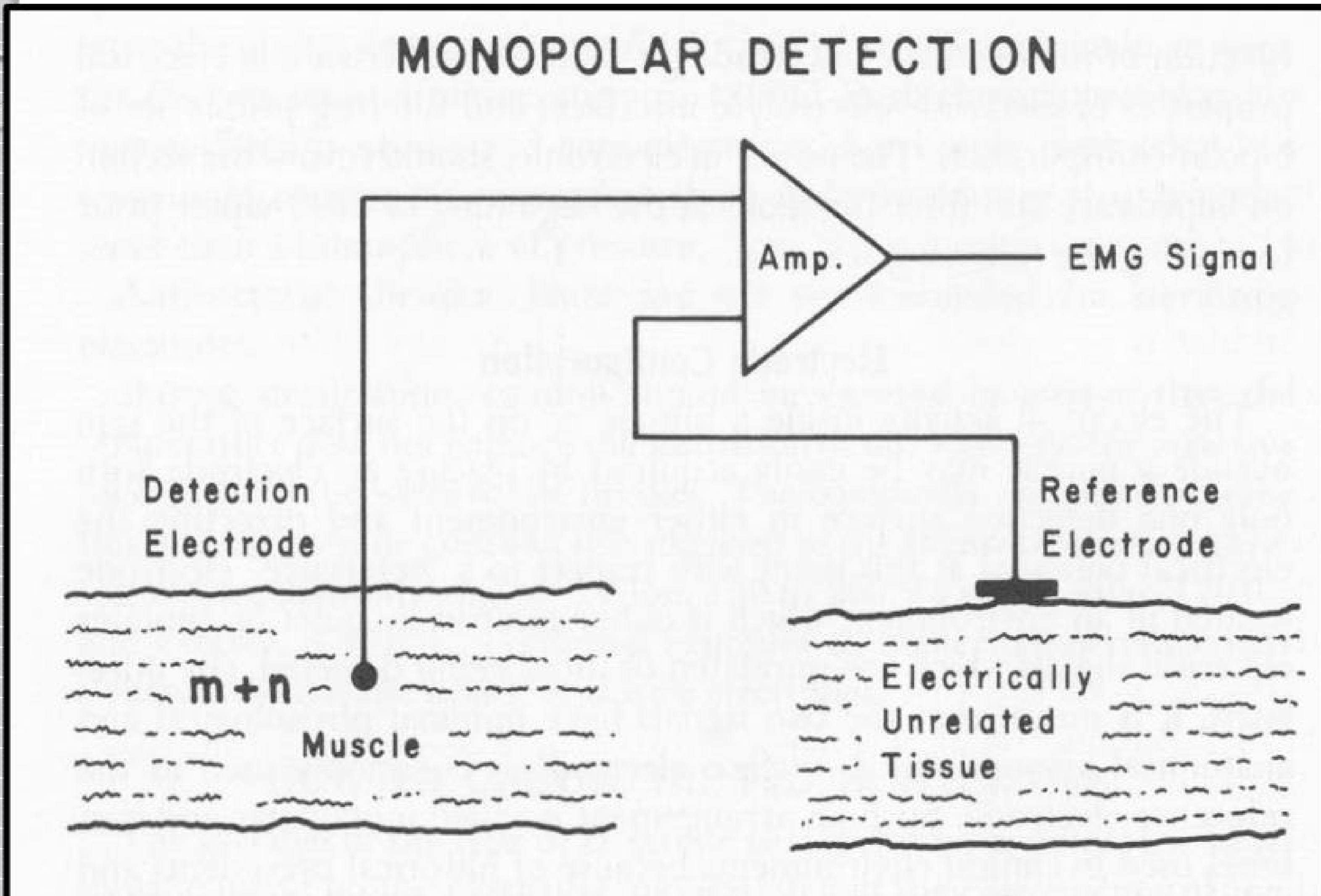
Amplifier

The electrical potential recorded by the electrodes is composed of EMG signal from mm contraction and unwanted noise

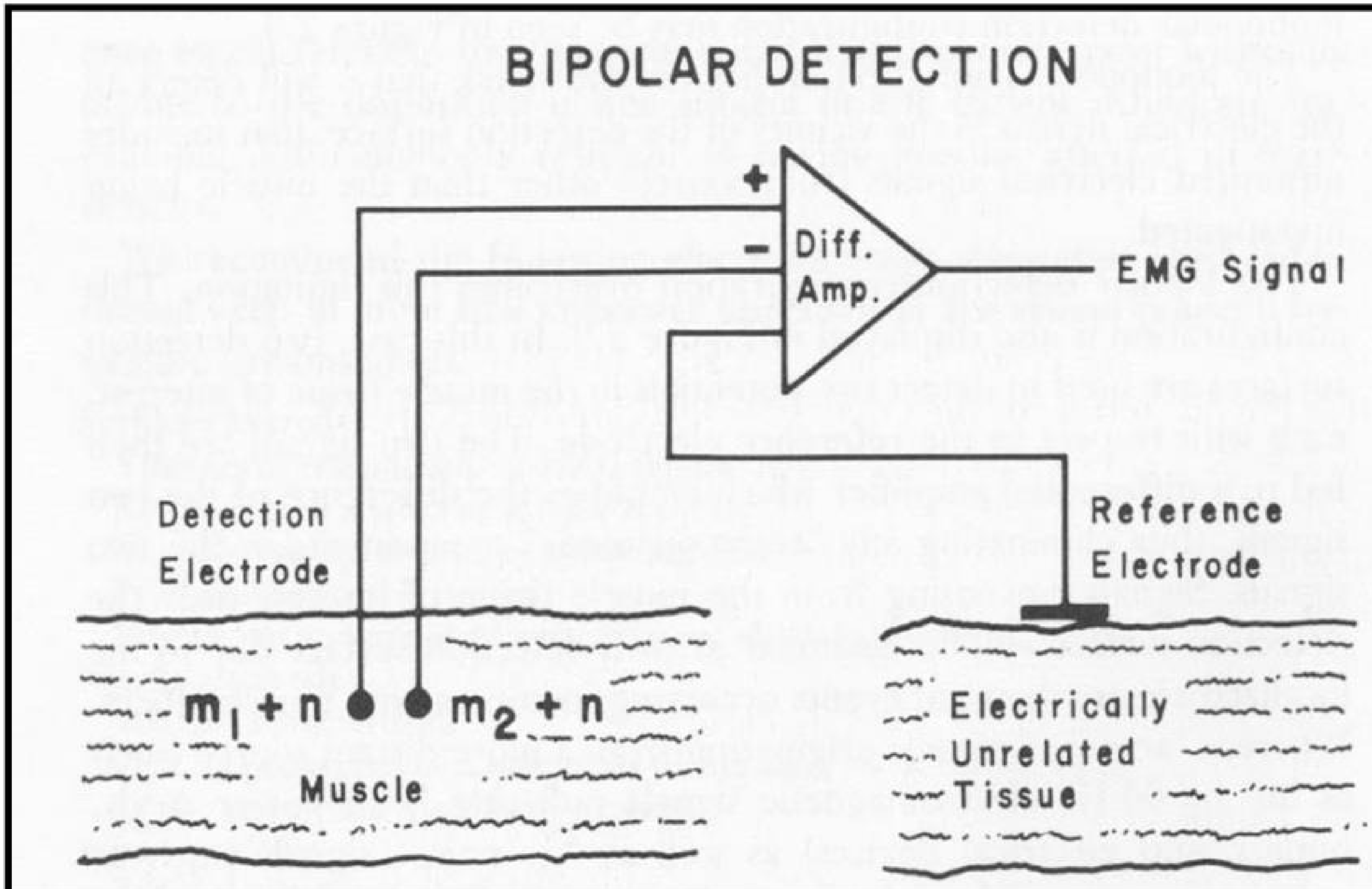
EMGs use *differential amplifiers*

- Ground electrode and active electrode supply input to the amplifier
- Difference between the signals will be amplified and recorded
- If two electrodes receive equal signals, no activity is recorded

Amplifier


MONOPOLAR DETECTION
Amp.
EMG Signal
Detection
Electrode
Reference
Electrode
m+n
Muscle
Electrically
Unrelated
Tissue

Amplifier



BIPOLAR DETECTION
+
-
Diff.
Amp.
EMG Signal
Detection
Electrode
Reference
Electrode
m1 + n
m2 + n
Muscle
Electrically
Unrelated
Tissue

Amplifier

Common Mode Rejection Ratio

- Measure of how much the desired signal is amplified relative to the unwanted signal
- The higher the value, the better
- A good differential amplifier should have a CMRR exceeding 100,000:1

Amplifier

Signal-to-noise Ratio

- Reflects the ability of the amplifier to limit noise relative to amplified signal
- Ratio of wanted to unwanted signal
- Noise generated from
  - Internal electrical components

Amplifier

Gain

- Refers to amplifier's ability to amplify signals
- Ratio of output signal to input signal level

Amplifier

Input Impedance

- Resistive property observed in AC circuits
- Reduced by:
  - Larger electrodes
  - Skin preparation

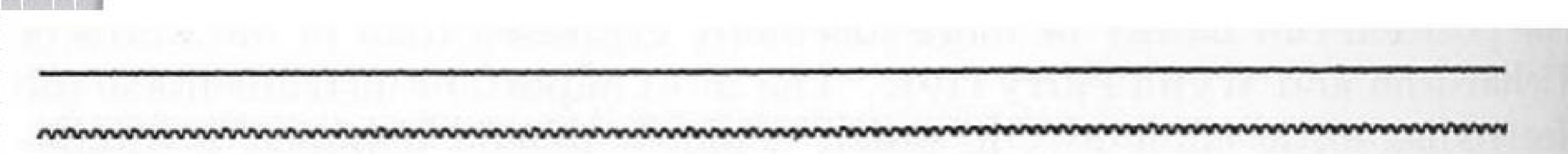
NORMAL EMG

Insertional activity

- Caused by the needle breaking through muscle fiber membranes
- Also seen during needle repositioning
- Normally stops when the needle stops moving.
- May be described as
  - Normal
  - Reduced
  - Prolonged

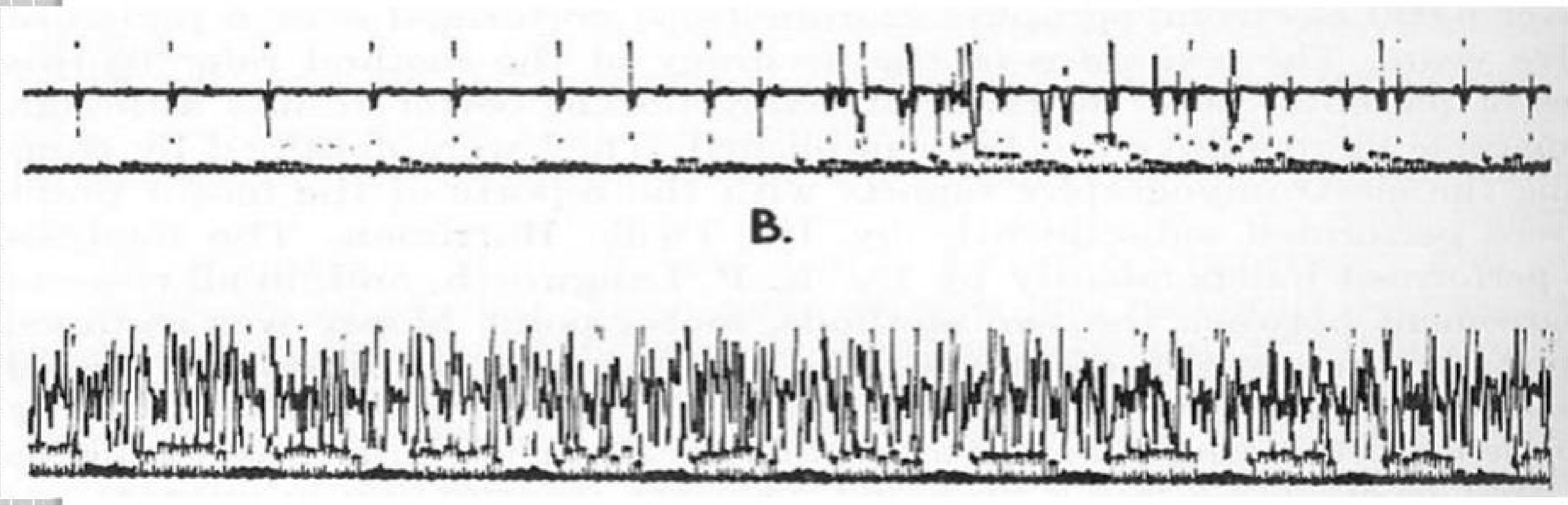
Electrical Silence

- (-) electrical activity
- If needle is at the NMJ/motor end plate, very small spontaneous potentials may be observed
- Any other activity observed indicates pathology



Interference Pattern

- Normally seen with strong muscular contraction
- Individual potentials are summated with increasing number of motor units firing at higher frequencies



ABNORMAL EMG

Fibrillation Potentials

- Represents spontaneous, repetitive depolarization of a single mm fiber
- NOT visible
- May result from
  - Denervation
  - Metabolic dysfunction
  - Inflammatory diseases (polio)
  - Trauma
  - Indicative of LMN lesions

Fibrillation Potentials

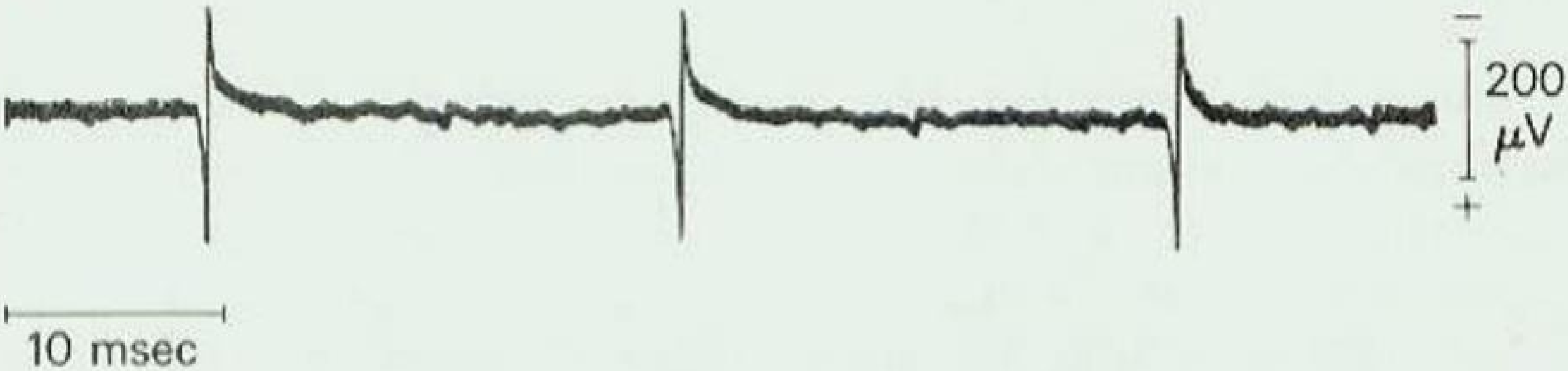
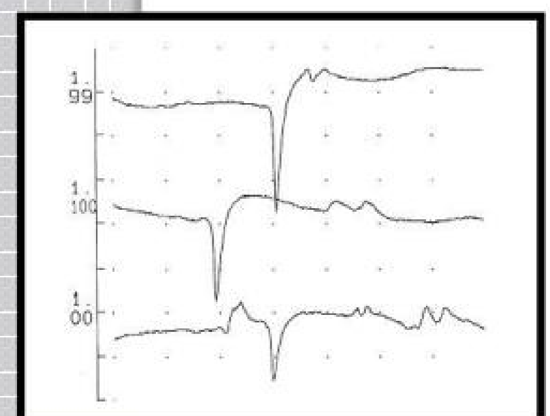


Figure 2.5 Fibrillation potentials in partially denervated muscle.

Positive sharp waves

- Represents asynchronous discharge of a number of denervated mm fibers
- Reflects an altered membrane excitability
- Usually accompanied by fibrillation potentials

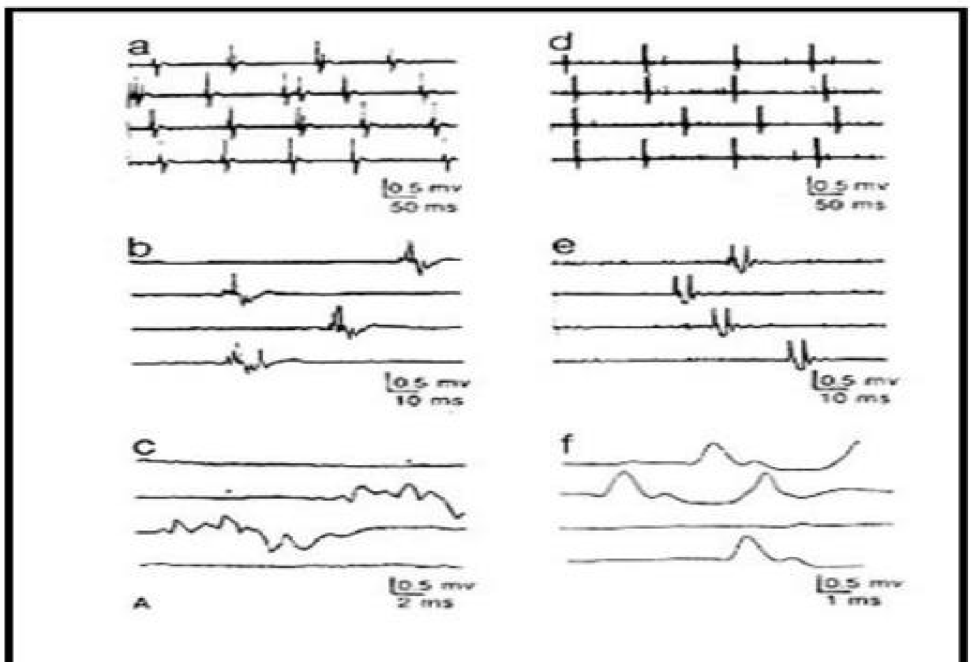


Fasciculation Potential

- Represent spontaneous discharges from a group of mm
- Often visible; small mm twitches
- Seen with irritation or degeneration of ant horn cell, chronic pni, nerve root compression, cramps or spasms

Fasciculation Potential

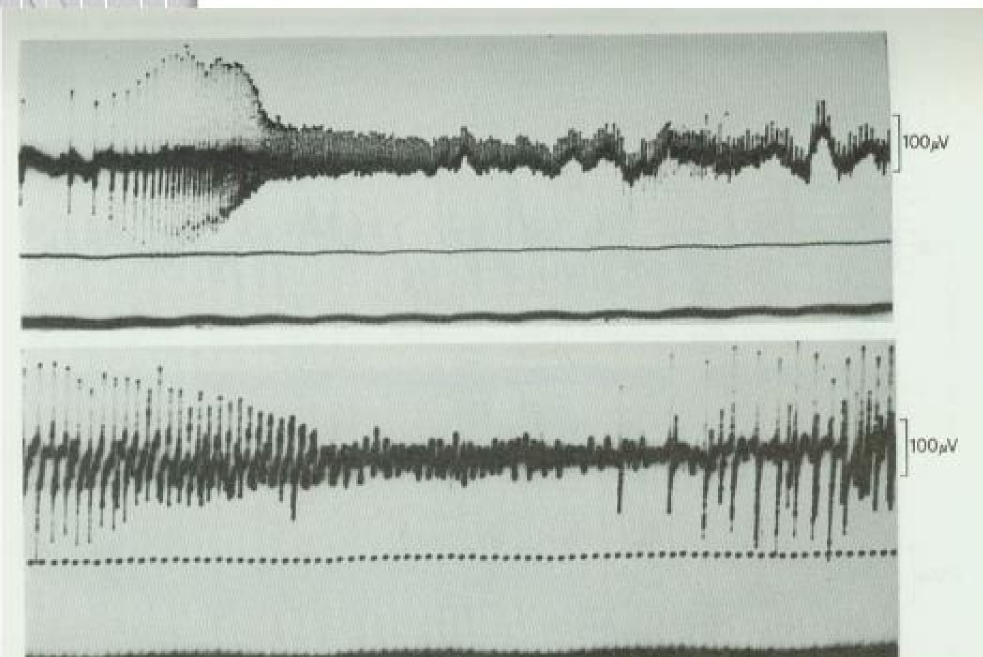
- May be seen in NORMAL individuals
- Pathological significance if seen with fibrillation and positive sharp waves

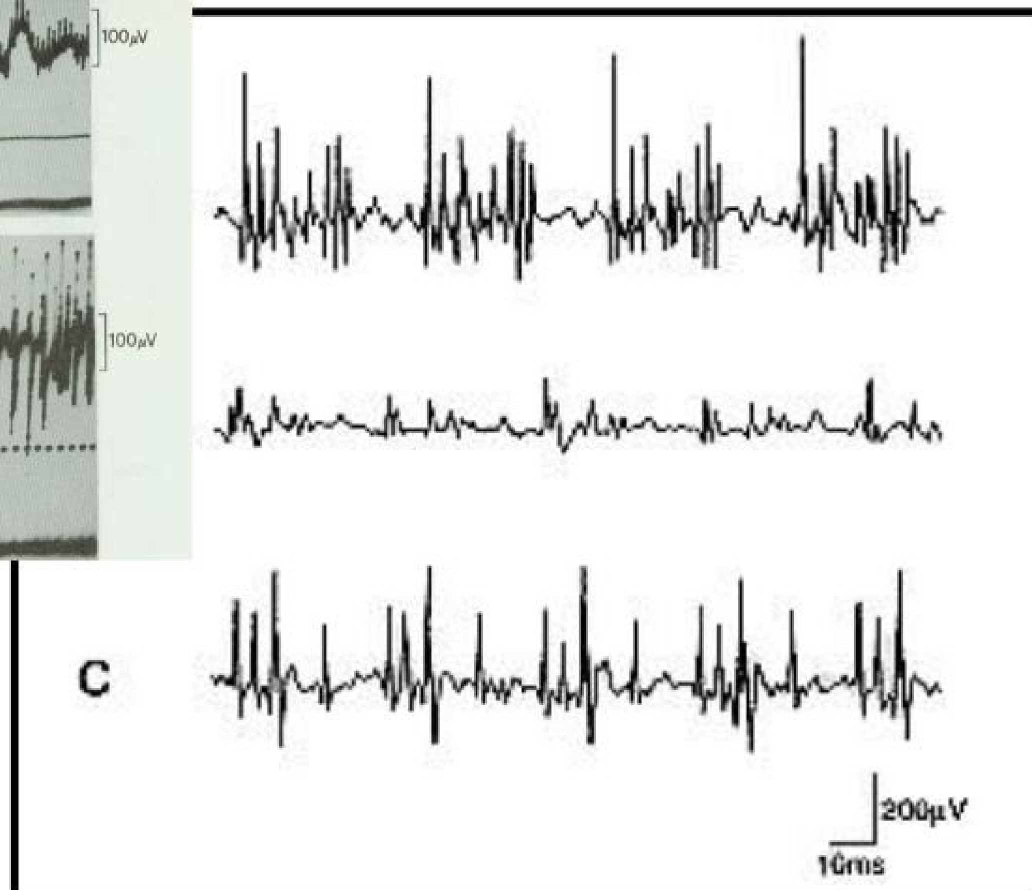


Myotonic / Complex Repetitive Discharge

- Seen with lesions of the anterior horn cell and peripheral nerves, myopathies
- Dive-bomber sound that occurs on needle insertion, voluntary contraction
- Probably triggered by movement of needle electrode within unstable mm fibers

Myotonic / Complex Repetitive Discharge





Nerve Conduction Velocity (NCV)

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Objectives

At the end of the session, you should be able to:

- Discuss the principles of NCV
- Describe motor NCV testing
- Describe sensory NCV testing

Principles

- Involves direct stimulation to initiate an impulse in motor or sensory nerves (evoked potential)
- The conduction time is measured to determine the presence or absence of a lesion
- It provides data on the ability of the nerve to transmit impulses

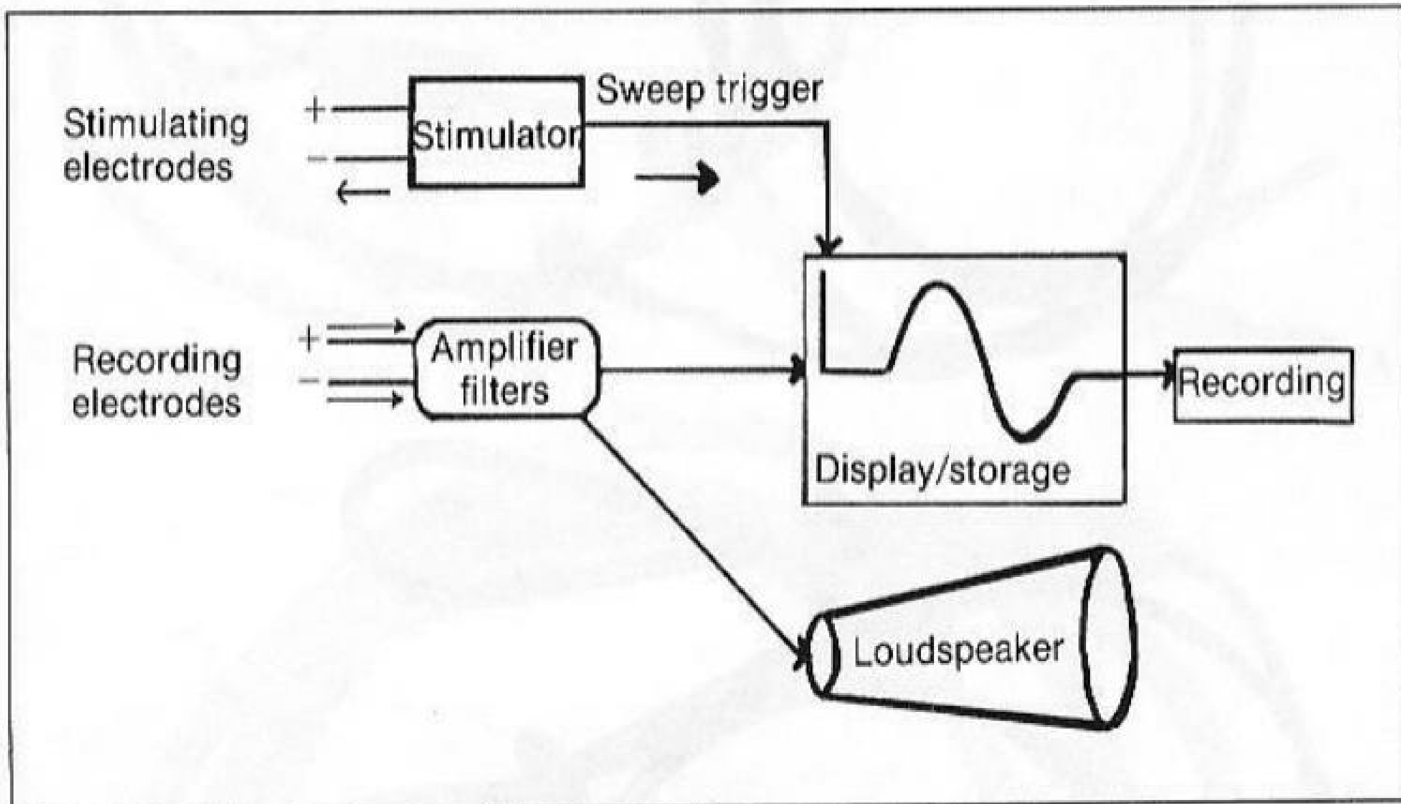
Stimulating electrode

- Bipolar electrode with anode and cathode
- Pulse duration: 0.1 msec
- Frequency: 1Hz
- Contraindicated in patients with
  - Indwelling cardiac catheter
  - Central venous pressure line

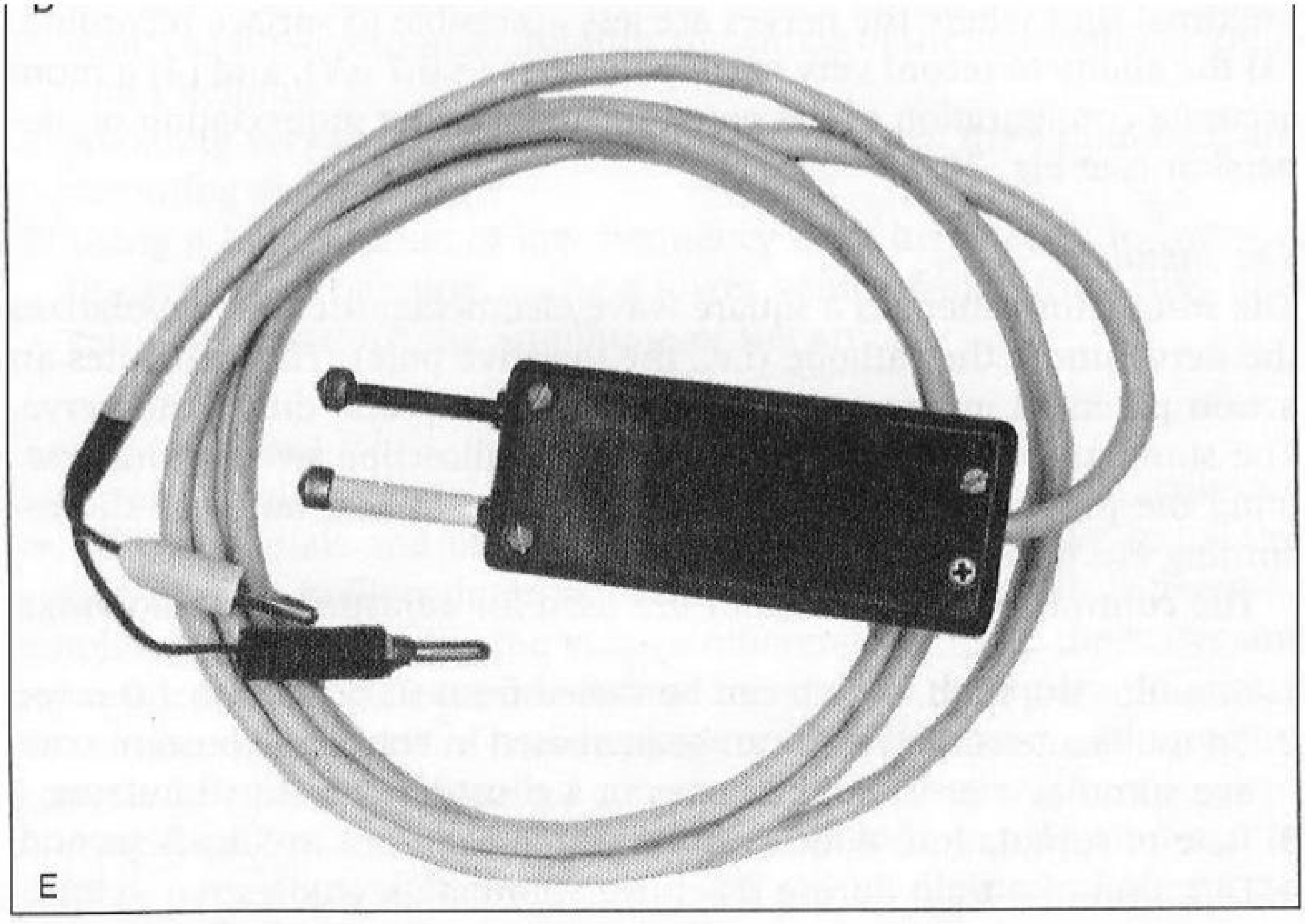
Stimulating electrode

Apparatus

Figure 1-1 outlines the basic components of the apparatus used for nerve conduction studies, namely the electrodes, stimulator, amplifier, filters, display screen, and recording mechanism.



Stimulating electrode



E

MOTOR NCV TESTING

Stimulation and Recording

- Evoked potential recorded from a distal muscle innervated by the nerve under study
- Small surface electrodes are used to record the evoked potential from muscles

Stimulation and Recording

Recording electrode

- Placed over the belly of test muscle

Reference electrode

- Over the tendon of the mm; distal to the active electrode

Ground electrode

- Placed over a neutral area between the electrodes and the stimulation site

Stimulation and Recording

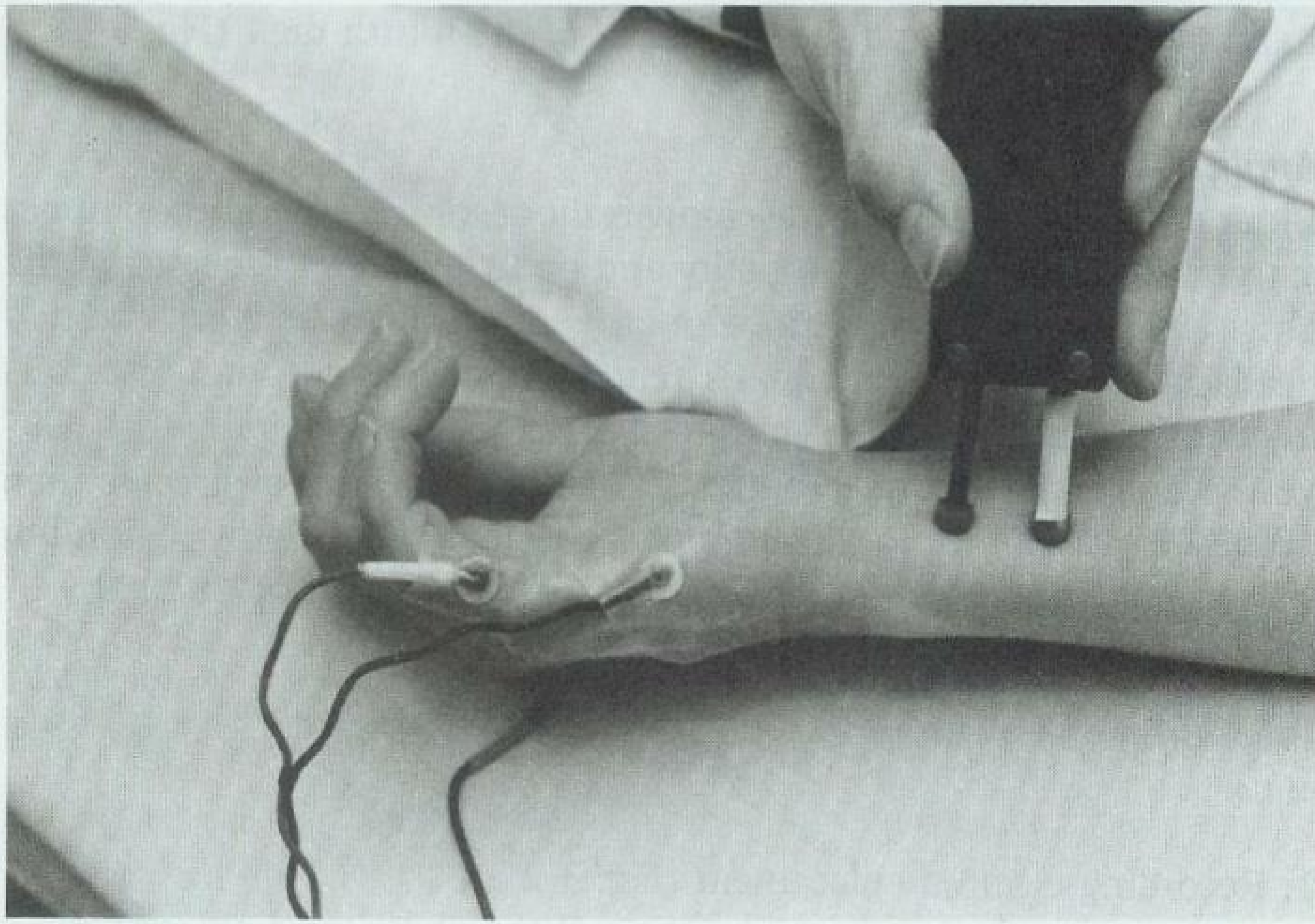


Figure 3-2. *Electrode placement for recording from the abductor digiti quinti and stimulation of ulnar nerve at the wrist.*

Stimulation and Recording

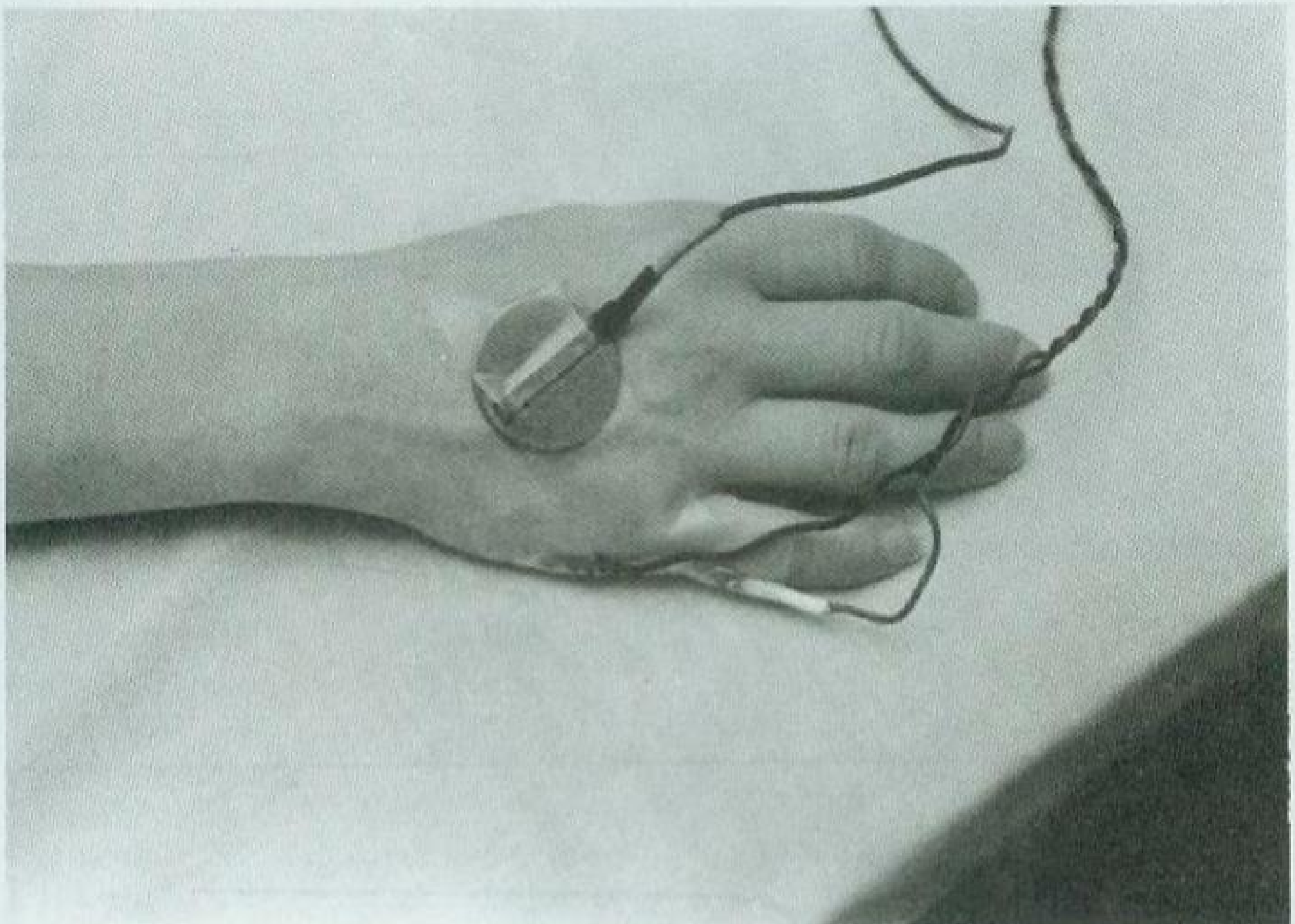


Figure 3-3. Placement of the ground on the dorsum of the hand.

Stimulation and Recording

- Stimulus starts low and is slowly increased
- Intensity is increased until the evoked response no longer increases in size
- Supramaximal stimulus
- M-wave

Stimulation and Recording

Conduction velocity

- Determined by dividing the distance between the two points by the difference between the two latencies
- Meters/second
- Proximal latency
- Distal Latency

Stimulation and Recording

For example:

Proximal latency: 7msec

Distal latency: 2 msec

Conduction distance: 300 mm or 30 cm

$$CV = 30\ cm\ /\ (7msec - 2\ msec)$$
$$= 30\ cm\ /\ 5\ msec$$
$$= 60\ m/s$$

Stimulation and Recording

How to interpret?

- Upper Extremity: 50 – 70 m/s [60 m/s]
- Lower Extremity: 60 m/s

SENSORY NCV TESTING

Stimulation and Recording

- Ring electrodes

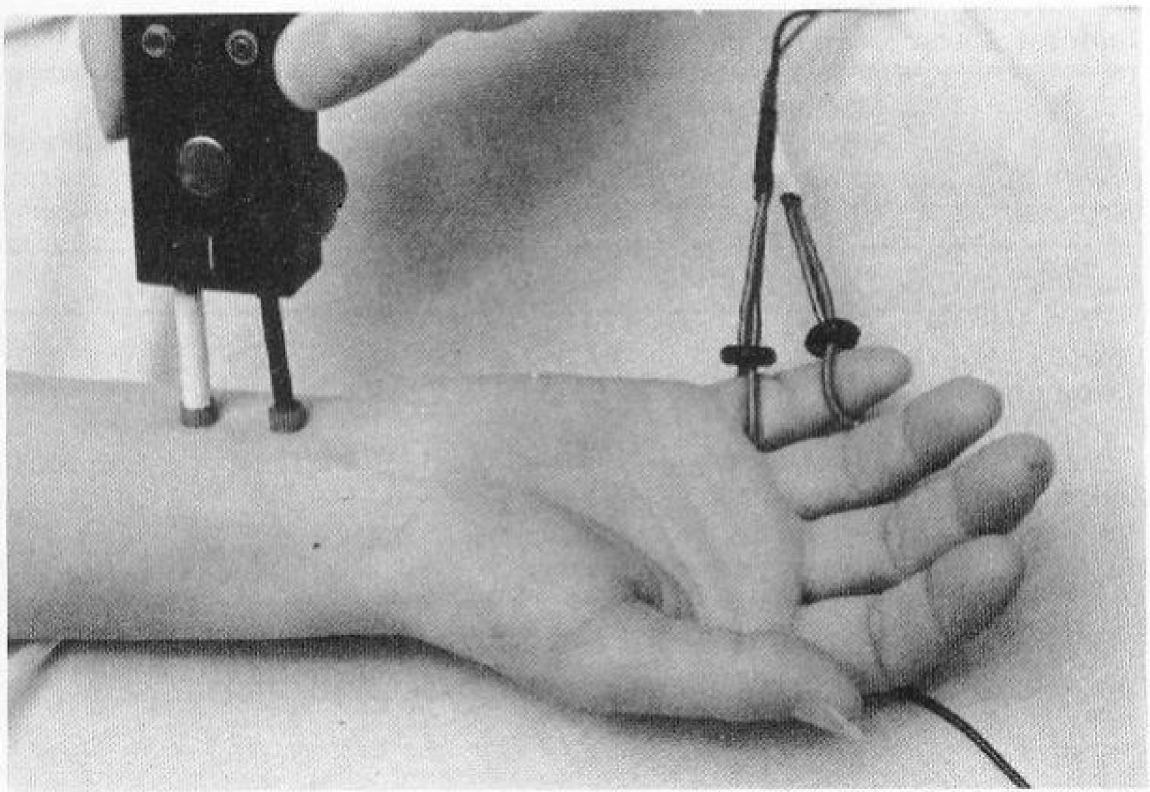


Figure 3-8. Electrode placement for antidromic recording of ulnar nerve sensory responses.

Stimulation and Recording

Techniques

- Orthodromic conduction
- Antidromic conduction

Stimulation and Recording

Orthodromic conduction

- Normal way physiologic responses travel

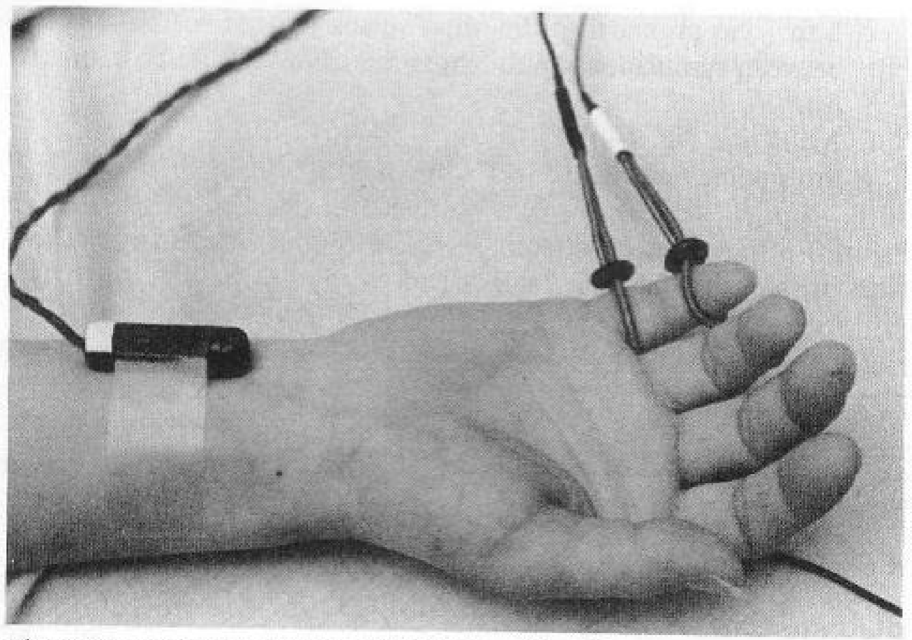


Figure 3-7. Electrode placement for orthodromic recording of ulnar nerve sensory responses.

Stimulation and Recording

Antidromic conduction

- Stimulus applied to proximal sites and is recorded at the index or long finger

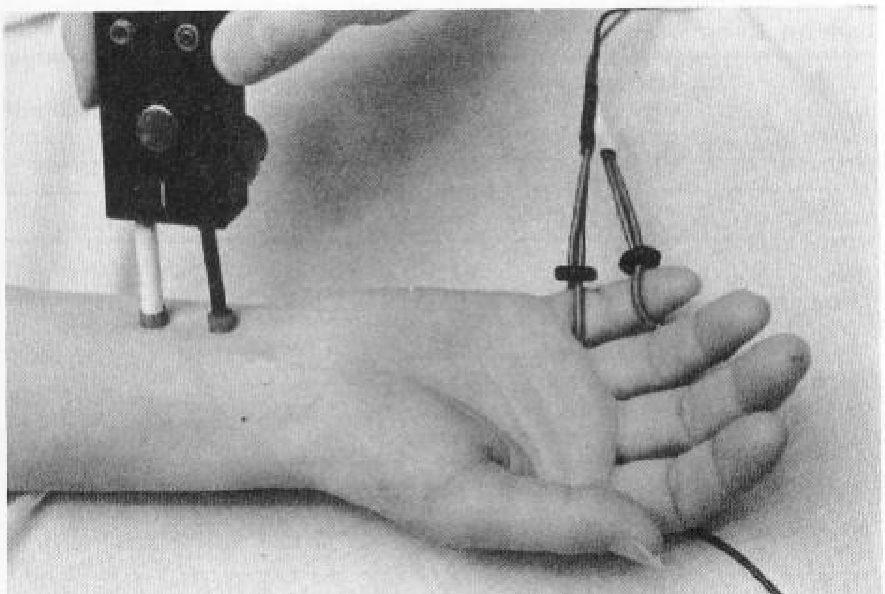


Figure 3-8. Electrode placement for antidromic recording of ulnar nerve sensory responses.

Stimulation and Recording

How to interpret?

- Normal sensory NCV
  - 40 – 75 m/s
- Sensory NCVs have been found to be faster compared with the motor NCVs

Factors that may affect motor and sensory conduction

- Increase in body temperature
  - 5% increase in conduction velocity per degree
  - Reduced latencies
- UE faster than LE
- Proximal segments faster than distal segments

OTHERS

H Reflex

- Hoffman Reflex
- Measures the integrity of both motor and sensory fibers
- For example
  - Submaximal stimulus to the tibial n. in the popliteal fossa
  - Motor response recorded from the medial soleus (rich in mm spindles)
- Norm: 29.8 msec

F Wave

- Elicited by
  - Supramaximal stimulation of a peripheral nerve in a distal site resulting in both orthodromic and antidromic conduction.
  - Antidromic conduction extends to the spinal cord
  - Most helpful in conditions where the most proximal portion of the nerve is affected
- UE: 30 seconds
- LE: less than 60 seconds